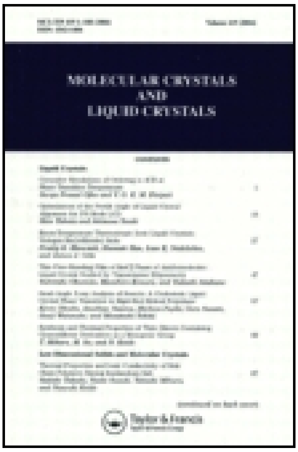

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Characterizations of Polyimide Langmuir Blodgett Films for Nematic Liquid Crystal Alignment

Hiroyuki Abe [a b], Makoto Chizaki [a], Yasufumi Iimura [a] & Shunsuke Kobayashi [a]

[a] Division of Electronic and Information Engineering, Faculty of Technology, Tokyo University of Agriculture & Technology, 2-24-16 Nakamachi, Koganei, Tokyo, 184, Japan

[b] SEIKO EPSON Corporation, 392 Suwa-shi, Owa, 3-3-5, Japan

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Characterizations of Polyimide Langmuir Blodgett Films for Nematic Liquid Crystal Alignment

HIROYUKI ABE*, MAKOTO CHIZAKI, YASUFUMI IIMURA
and SHUNSUKE KOBAYASHI

Division of Electronic and Information Engineering. Faculty of Technology, Tokyo University of Agriculture & Technology, 2-24-16 Nakamachi, Koganei, Tokyo 184, Japan

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In order to apply polyimide Langmuir Blodgett films to nematic liquid crystal (NLC) alignment, the optimum deposition conditions have been studied by measuring the azimuthal anchoring energy of 5CB aligned on the film. Special attention is paid to obtain good NLC alignment on the Z-type PI-LB flims, and we firstly prove that, by choosing the proper deposition conditions, the Z-type films show better performances of NLC alignment than Y-type films. The obtained azimuthal anchoring energy of the Z-type film exceeds 10^{-5} J/m^2, which is the strongest azimuthal anchoring energy of PI-LB films reported so far.

Keywords: Liquid crystal, polyimide langmuir blodgett film, azimuthal anchoring energy, Z-type PI-LB film

1. INTRODUCTION

Recent great sucess in industrial fields of liquid crystal displays (LCDs) owes much to the progress of liquid crystal alignment technologies, and thus much effort has been paid to develop new alignment polymer materials and alignment methods.

In particular, a rubbing method using polyimide films[1] is now becoming a very promising technique for the LCD production because of its simplicity and relibility. But since the rubbing process is essentially incompatible with a clean environment there is also a strong demand to develop rubbing-free techniques to control LC alignment. Until now, several rubbing-free techniques to control LC alignment have been developed,[2–7] and the device operations of LCDs using these techniques were demonstrated. Using polyimide Langmuir Blodgett (PI-LB) films, which is one of the rubbing-free techniques, is constantly attracting people's interest and many studies on this subject were reported.[8,9] Quantitative characterizations of the PI-LB film for LC alignment, however, not so well established.

In this paper, we present detailed studies on PI-LB film deposition and give the optimum deposition conditions of the films for the NLC alignment application.

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* Present address: SEIKO EPSON Corporation, 392 Suwa-shi, Owa, 3-3-5, Japan.

2. EXPERIMENTAL

In order to prepare a PI-LB film on an ITO-coated glass substrate, polyamic acid alkyl salt (PAAS) molecules spread onto the water surface (15°C) were firstly deposited on the substrate by a vertical dipping LB method, which was performed using home-built LB equipment with two movable barriers. The deposited PAAS-LB films on the substrate were converted to PI-LB film by using a solvent treatment and then thermally cured at 170°C for 30 min.[8] An ITO-coated glass substrate used was hydrophilically treated so that the deposition was initiated by withdrawing the substrate.

The LC cells used were the sanwich-type, where one of the inner surfaces of the glass substrate was coated with PI-LB film and the other one with a strongly rubbed PI-LB film. The cell was assembled to form a twisted nematic (TN) configuration, setting the angles of the two easy axes corresponding to dipping and rubbing directions to be 85 deg. A nematic liquid crystal of 5CB was injected into a cell ~ 10 μm thick in an isotropic phase. Measurements of the azimuthal anchoring energy were conducted at the cell temperature of 5°C below the clearing point.

The azimuthal anchoring energy at an LC/PI-LB interface was estimated by measuring the actual twist angle of the LC cells, in which we assume weak anchorage at the PI-LB surface and strong anchorage at the rubbed PI-LB film.[10] Considering the spatial variation of the azimuthal angle of the LC director shown in Figure 1, the extrapolation length d_e at the LC/PI-LB interface can be calculated to be

$$d_e = \frac{(\Phi - \Delta\varphi)d}{\Delta\varphi}, \tag{1}$$

where Φ and $\Delta\varphi$, respectively, represent the intended twist angle (85 deg.) and the actual twist angle of the LC cell. d is the cell thickness. The anchoring energy is then obtained by combining a torque balance equation at the LC/PI-LB interface with the Rapini-Papoular formalism.[10] The following equation of the azimuthal anchoring energy A_φ is derived,

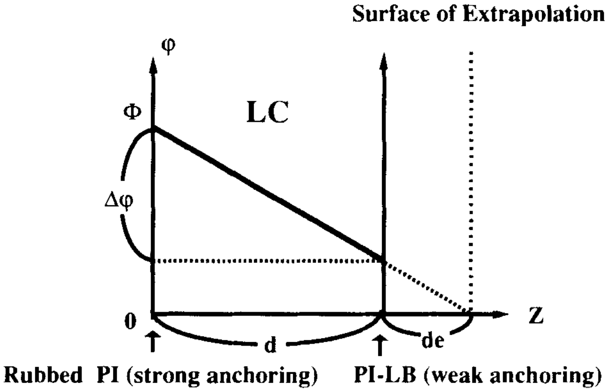

FIGURE 1 A schematic illustration of the twisted configuration of the LC director in a TN cell. Φ is the angle of intended twist angle, and $\Delta\varphi$ is the actual twist angle.

$$A_{\varphi} = \frac{2K_2 \cdot (\Phi - \Delta\varphi)}{d_e \cdot \sin\{2(\Phi - \Delta\varphi)\}}, \tag{2}$$

where K_2 is an elastic constant for a twist deformation. Therefore, the azimuthal anchoring energy at the LC/PI-LB interface can be estimated by measuring the actual twist angle of the LC cell. The measurements of the twist angle of the TN cell were carried out using the methods reported in previous paper.[11]

3. RESULTS AND DISCUSSION

Figure 2 shows the dependence of the azimuthal anchoring energy on the transfer speed of glass substrates during LB firm deposition. The surface pressure during the LB deposition was kept constant 25 mN/m, which resulted in the formation of a Y-type film on the substrate.

From the figure, it is clear that the azimuthal anchoring energy gradually decreases and tends to saturate by increasing the transfer speed, indicating the lowering of the orientational order of the backbone of the stacked PAAS molecules on the substrate. It is theoretically reported[12] that, in a vertical LB deposition mode, alignment of the backbone of PAAS molecules on the glass substrate is caused by the unidirectional motion of the substrate and becomes better by increasing the transfer speed of the substrate. The disagreement between our experimental and theoretical results may arise from the tightness of the PAAS-Langmuir film. As the transfer speed of a substrate

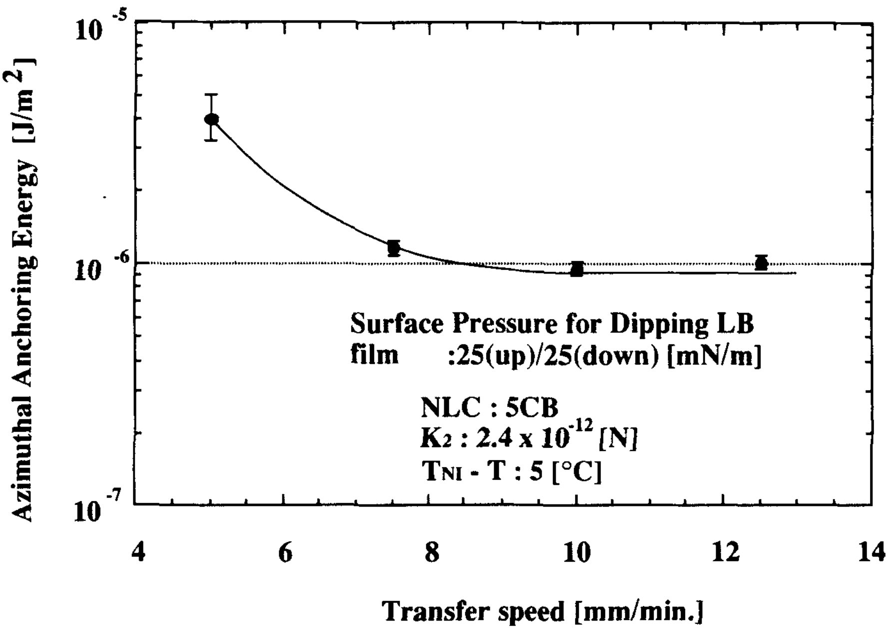

FIGURE 2 The dependence of the azimuthal anchoring energy on the transfer speed of a glass substrate.

increases, the friction acting between the side walls of a LB through (also the glass substrate) and L-film disturbs the uniformitiy of the L-film, leading large domains of L-film to small ones. The resulting stacked LB film on the glass substrate may become inhomogeneous and the anchoring energy is reduced with increasing the transfer speed.

In order to study the effect of the stacked number of LB layers on the azimuthal anchoring energy, firstly Y-type LB films with the surface pressure of 25 mN/m (a withdrawing period) and 20 mN/m (a dipping period)[10] were deposited on ITO-coated glass substrates, and the azimuthal anchoring energy of the cells was measured. We kept the transfer speed of 5 mm/min. by taking the result in Figure 2 into account.

As shown in Figure 3 by closed circles, the azimuthal anchoring energy increases with the stacked number of LB layers and, after showing the maximum at around 5 LB layers, the anchoring energy gradually decreases as the stacked number increases. One of the reasons for this decrease may result from the degradation of the amphilic nature of the L-film due to losting the alkyl chains from PAAS molecules.[13] As indicated by open circles, the decrease can be reduced by refreshing a L-film on water after 5 layers of a LB film are stacked onto a substrate. But the effect of the refreshment is not so large. The previous investigations showed that the optical birefringence for every LB layer had almost the same behavior as shown in Figure 3 and the maximum birefingence appeared at around five LB layers.[14] This suggests the strong correlation between the optical birefringence and the azimuthal anchoring energy. It should be noted that the magnitude of the optical birefringence of a LB film can be considered to be proportional to the orientational order of the LB film and thus the azimuthal anchoring

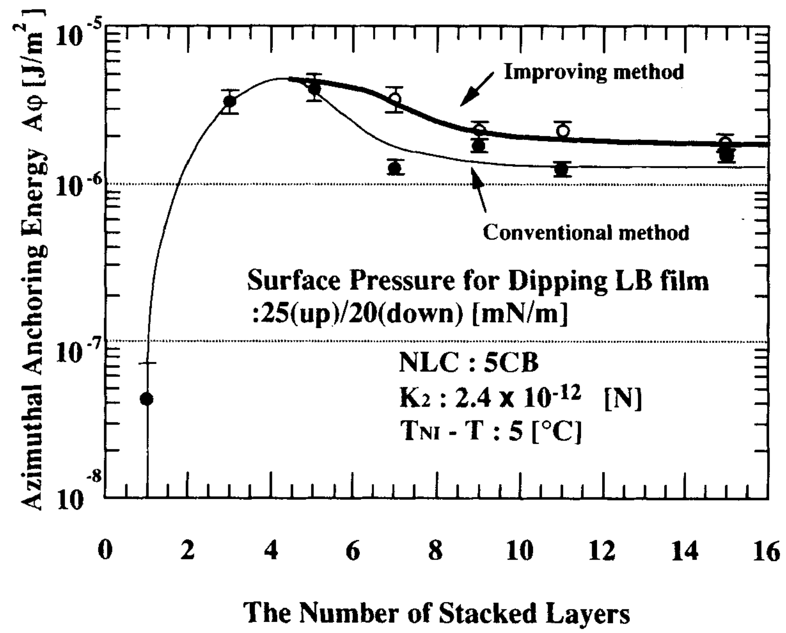

FIGURE 3 The stacked number of LB layers vs. the azimuthal anchoring energy. A little improvement of the azimuthal anchoring energy is achieved by spreading freshly prepared PAAS solution.

energy is good measure to judge the orientational order of the LB film. At this stage, we can not say why the maximum anchoring energy is obtained at around 5 LB layers, and a further study is needed to clarify it.

There were several reports comparing the LC alignment ability of Y-type and Z-type PI-LB films.[13,15] In these studies, Y-type PI-LB film shows a better performance to align LC molecules than Z-type films. From the view point of chemical stability, Y-type PI-LB films are superior to Z-type films. From our experiments, it is rather difficult to obtain a good transfer ratio of a L film for Y-type PI-LB deposition in comparison with that for Z-type PI-LB deposition. Therefore it is interesting to quantitatively compare the LC alignment capability for these two kinds of LB films. Figure 4 compares the dependence of the azimuthal anchoring energy as a function of the stacked number of the LB layers. In this figure, the surface pressure during the withdrawing and dipping periods were 25 and 20 mN/m[10] for Y-type and 25 and 5 mN/m for Z-type films with the constant transfer speed of 5 mm/min. The surface pressure during the dipping period for the Z-type film deposition was decided by judging from a negligible transfer ratio of a L-film to a glass substrate. From the figure, the overall behavior of the azimuthal anchoring energy vs. the stacked number of LB layers is quite similar, but the Z-type LB film with around 5 layers gives higher anchoring than the corresponding Y-type films, and the maximum anchoring energy exceeds $\sim 10^{-5}$ J/m^2. This result may be understood by considering the poorer transfer ratio for Y-type films compared with that of Z-type films. This superiority in the LC alignment capability is also confirmed by the observation of the microscopic texture as shown in Figures 5(a) and 5(b). The cells were constructed with homogeneous configuration and the observations were carried out in the dark state. It is clear from the photographs that darkness and the uniformity of the texture for the Z-type film are better than those for the Y-type films,

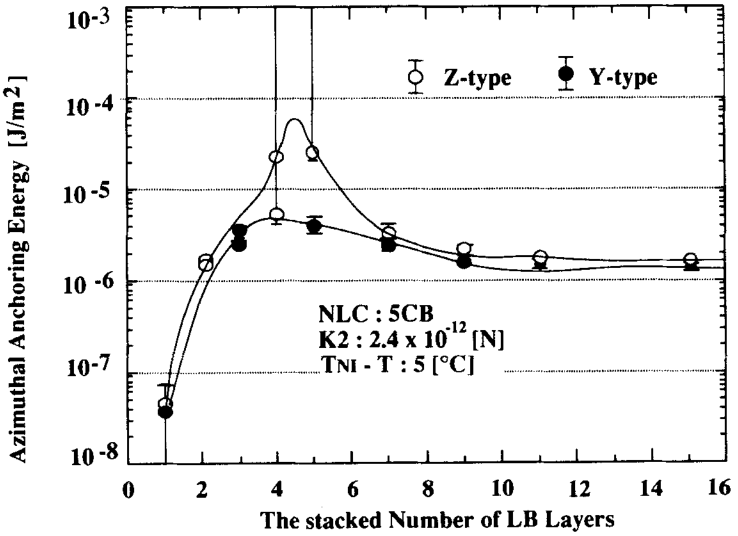

FIGURE 4 Comparison of the azimuthal anchoring energy for Y- and Z-type LB film.

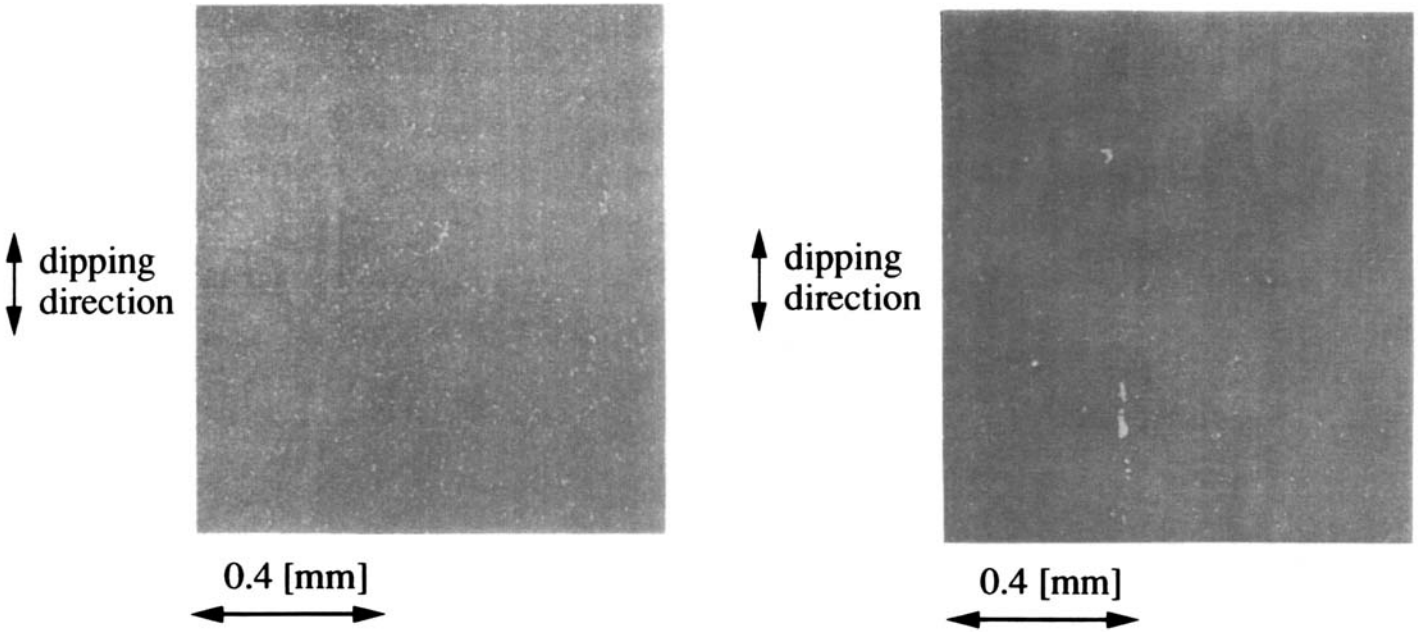

FIGURE 5 Comparison of the microscopic textures for using (a) Y-type and (b) Z-type LB-films under the cross nicol condition.

indicating the superior LC alignment capability of the Z-type films to the Y-type films.

4. CONCLUSION

In conclusion, we demonstrated the detailed characteristics of PI-LB films for NLC alignment application by measuring the azimuthal anchoring energy. The result suggested that lowering the transfer speed of a glass substrate resulted in the high anchoring energy and Z-type LB films had a superior LC alignment capability to Y-type LB films. We also proved that PI-LB films with around 5 LB layers showed high NLC alignment capability. The experimental result in this work indicates the usefulness of PI-LB films to control LC alignment.

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